

Rotating Field Mass Spectrometer for Organic Compound Detection

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The JPL/Tap sponsored Miniaturized Rotating Field Mass Spectrometer will be discussed. A description and application of the instrument will be presented for in situ sampling of atmospheric gasses, and dissolved gas, liquids and/or solutes characteristic of water/ice/ocean environments as well as protein characterization that leads to microbial identification. The instrument, scaled to an extremely small dimension, is capable of high mass resolution measurements of both small and large mass (>3000 amu) compounds. It can directly and simultaneously measure ozone, O_2 , water, organic species (DNA fragments), etc. present in both air and liquid environments. The protein/peptide compounds detected would help to aid in unambiguous microbial identification. It can also mass analyze lighter dissolved gasses and mineral solutes present in an atmospheric or deep sea water environment. Further laboratory demonstrations as well as field demonstrations of the instrument can be made. An extremely large number of mass sampling missions can be envisioned, for example one version is for direct measurement of the O_{16}/O_{18} and Deuterium isotope ratio of glacial ice in Greenland.

- A. Miniature submersible version of the RFMS Mass Spectrometer uses radio frequency RF fields in a unique method which incorporates both high mass resolution (better than 1 part in 300) and high mass collection range (>2000 amu), within a compact and lightweight package. The RFMS is presently miniaturized so that all electrical and pressure/vacuum components occupy a total volume is approximately that of a small "briefcase". Additional miniaturization of pumps and rf generators is very possible. Liquid samples are directly injected via a micro-size electrospray nozzle (liquid/vacuum interface) into a compact sampling vacuum chamber. Atmospheric gas samples are admitted through an osmotic membrane boundary. There are no thermal filaments, and vacuum levels need only be at the millitorr level.
- B. Technical Description The RFMS uses "rotating" RF electric fields¹. It consists of an ionizer, a mass spectrometer and an ion detector. The sampled ions are focused into a beam (200 eV energy with 1 eV energy width) which enters a cell-like region which has sinusoidal RF fields that are in the x- and y- direction and differ in phase by $\pi/2$ radians. The ions of a particular mass travel in a helix and impact an ion detector placed at the end of the cell. The ions generate a pattern which appears as a set of concentric circles, much like the lissajou figures that can be generated by a dual channel oscilloscope driven at the same frequency but with the channels differing by $\pi/2$ phase angle. The choice of RF frequency and amplitude determines the particular ion mass to be selected. The cell can be constructed to very small $1 \times 1 \times 10$ mm dimensions. A laboratory working version has been developed at JPL using a field ionization ionizer^{2,3} and has generated a preliminary mass spectrum with better than 1 part in 300 mass resolution. Calculations show that higher mass resolutions are possible. RF potentials on the side walls of the cells are scanned from 2 to 12 MHz, with a constant amplitude of about 20 volts. The ionizer, the mass spectrometer cell, and the ion detector (a Faraday cup collector or channelplate) are

mounted in a 2.75" Conflat type vacuum "tee". A 20 liter/sec ion pump provides sufficient vacuum pumping, as the system is rough-pumped before a mission and miniature leak valves and capillary delivery line provide for very small conductance of sample into the RFMS. A micro-size electrospray nozzle ionizer (ESI) is also incorporated. This allows for the direct analysis of protein fragments.

- C. **Progress and Results** The RFMS has measured argon and large organic compounds (C₆F₁₂, mass 300 amu), as well as tap water and sea water liquid samples where various mineral solutes are clearly seen. Figure 2 shows recent spectra. Seawater and samples from taken Pacific Ocean (Loihi) sediment and Greenland glacial melt water are currently being injected into the JPL device. On-line capillary nanospray interface capable of high-sensitivity MS in situ measurements has been established. Initial ionization design follows along the lines of Whitehouse et al.⁴ Average sized proteins in solution generate ion current on the order of 0.1 to 1.0 pA. Typical test samples are peptides (such as angiotensin) with masses in the 600-1500 amu range and mass-to charge ratio in the 200-1200 m/z ratio. Observed flow rates of less than 100 nanoliter/sec are seen using a simple sheathless nanospray interface. These are flame-drawn, uncoated fused silica needles with tip diameters in the 15-um range and inner diameters of 5 micrometer. Spray electric potentials up to 1 kilovolt are directly applied to the capillary union. On-line analysis will be performed at the 100 fmole/microliter or less concentration level. Electrospray ionization techniques will allow most of the sample to enter the first (and final) vacuum region. A laboratory sensitivity performance level is 5 to 0.5 pgram of an organic compounds such as adenosine dissolved in 0.5 mg of liquid solvent.

Figure 1. The experimental apparatus setup for gas sampling. Liquids are injected using a nanospray nozzle (not shown).

Figure 2. Shows Mass Spectrum of C₆F₁₂ (mass 300 amu) along with known and unknown contaminates. The estimated mass is less than 50 gm for the device plus the charged particle detector and the miniature ion source. Power consumption is estimated to be less than 10 watts, including ionizer load, RF power supply and ion pump. The presentation will include other higher resolution organic spectra.

References

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3. W. Aberth and C.A. Spindt, *Int J. Mass Spectrom. and Ion Phys.* 25, 183 (1977)
4. C.M. Whitehouse, R.N. Dreyer, M. Yamashita and J.B. Fenn, *Anal. Chem.* 57, 675 (1985).